U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-269 235

Lake Fort Phantom Hill Jones County, Texas

National Eutrophication Survey, Corvallis, Oreg

Prepared for

Corvallis Environmental Research Lab, Oreg

Mar 77

PB 269 235

U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

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N.E.P.S. 000-440

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.
3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE: Report on Lake Fort Phantom Hill, Jones County, Texas	5. REPORT DATE: Prepared March 1977
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Anonymous (National Eutrophication Survey Staff)	8. PERFORMING ORGANIZATION REPORT NO.: Working Paper # 644
9. PERFORMING ORGANIZATION NAME AND ADDRESS: National Eutrophication Survey U.S. Environmental Protection Agency 200 S. W. 35th St. Corvallis, Oregon 97330	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS: Office of Research and Development U.S. Environmental Protection Agency 401 M Street, S. W. Washington, DC 20460	13. TYPE OF REPORT AND PERIOD COVERED: Final - 1974
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Prepared in cooperation with the U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada 89114

16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

18. DISTRIBUTION STATEMENT: Release unlimited	19. SECURITY CLASS (This Report)	21. NO. OF PAGES: 47
	20. SECURITY CLASS (This page)	22. PRICE: PC A03 - A01

EPA Form 2220-1 (9-73)

REPORT

ON

LAKE FORT PHANTOM HILL

JONES COUNTY

TEXAS

EPA REGION VI

WORKING PAPER NO. 690

WITH THE COOPERATION OF THE

TEXAS WATER QUALITY BOARD

AND THE

TEXAS NATIONAL GUARD

MARCH, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John R. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

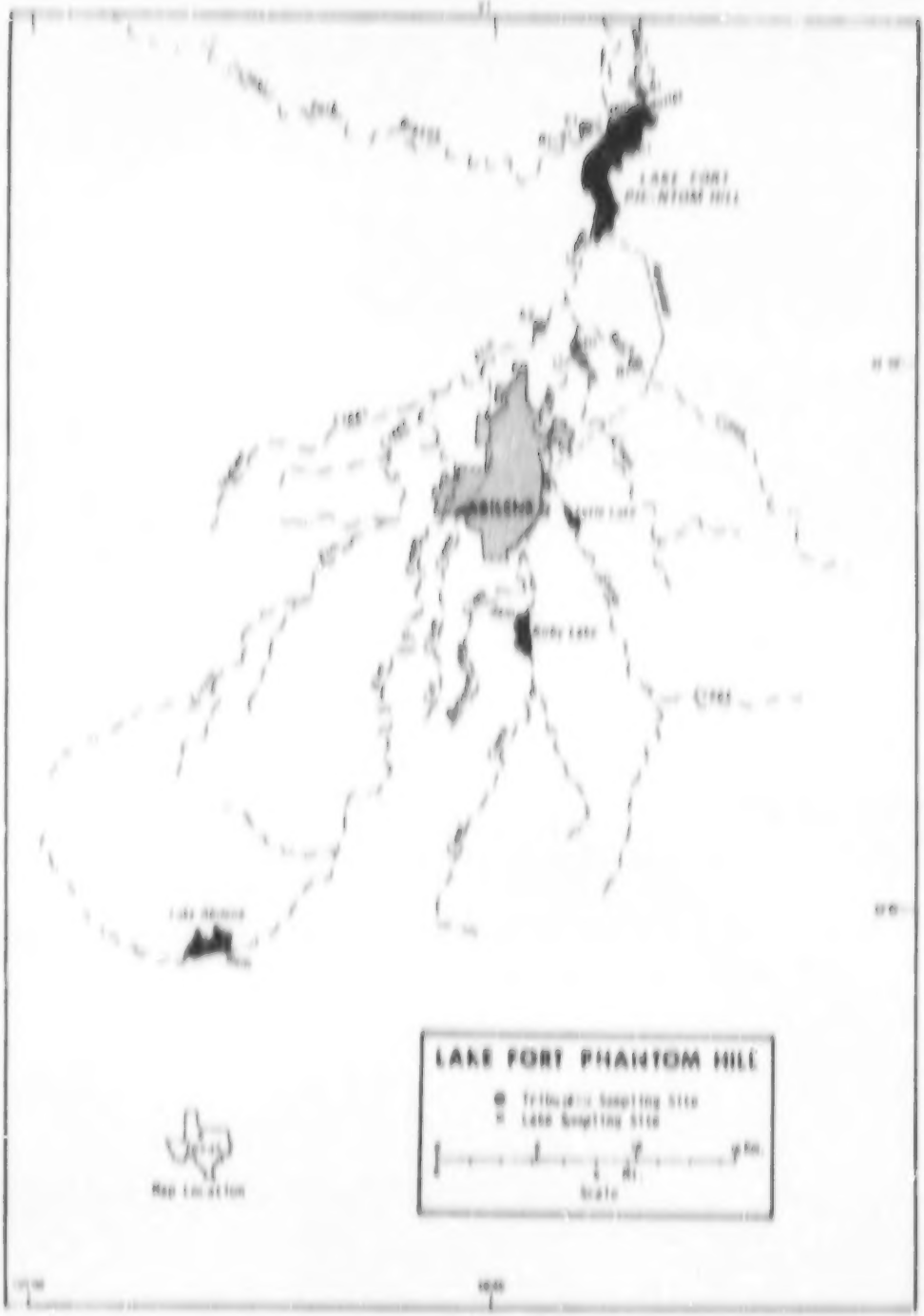
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lyndon B. Johnson	Burnet, Llano
Medina	Bandera, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


LAKE FORT
PHANTOM HILL
LAKE FORT PHANTOM HILL
Tributary Sampling Site
Lake Sampling Site
Scale
Map Location

LAKE FORT PHANTOM HILL

STORET 4814

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake Fort Phantom Hill is eutrophic; i.e., well supplied with nutrients and quite productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the lake. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no impairment of the designated beneficial uses of this water body.

Lake Fort Phantom Hill ranked twenty-fourth in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six water quality parameters*. Twenty-nine of the reservoirs had less median total phosphorus, 32 had less median dissolved orthophosphorus, 13 had less median inorganic nitrogen, ten had less mean chlorophyll a, and 30 had greater mean Secchi disc transparency.

No significant depression of dissolved oxygen occurred at any of the sampling stations and times. However, the lake is aerated from March to October to prevent stratification (Weems, 1976).

Survey limnologists did not observe macrophytes or surface algal concentrations during the sampling visits. However, it was noted that the lake at times was very turbid, and the low mean

* See Appendix A.

Secchi disc transparencies (range of 0.02 to 0.9 meters) indicate that at times primary productivity may be light-limited.

B. Rate-Limiting Nutrient:

The algal assay results indicate that nitrogen was the limiting nutrient in October. The lake data indicate nitrogen at all sampling times.

C. Nutrient Controllability:

1. Point-sources--No known wastewater treatment plants impacted Lake Fort Phantom Hill during the sampling year. Septic tanks serving lakeshore dwellings were estimated to have contributed about 3% of the total phosphorus load, but a shoreline survey would be necessary to determine the actual significance of these sources.

The present phosphorus loading of 0.37 g/m^2/year is slightly more than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 14). However, the hydraulic retention time of the lake is estimated and may be in error due to variability of inflows (see page 10).

2. Non-point sources--Non-point sources accounted for about 97% of the total phosphorus load reaching Lake Fort Phantom Hill. More than 49% of the total was contributed by the gaged tributaries, and an estimated 43% was contributed by the ungaged tributaries and immediate drainage.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 10.93 kilometers²,
2. Mean depth: 5.6 meters,
3. Maximum depth: ? meters,
4. Volume: 61,200 x 10^6 m^3,
5. Mean hydraulic retention time: 2.2 years (based on outflows).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)†††	Mean flow (m^3/sec)†††
Elm Creek	644.9	0.203
Cedar Creek	414.4	0.120
Clear Fork Brazos River diversion	-	0.237††
Minor tributaries & immediate drainage -	167.8	0.630
Totals	1,227.1	1.190*

2. Outlet -

Abilene Aqueduct	-	0.660††
Elm Creek	1,238.0**	0.208
Totals	1,238.0	0.868

C. Precipitation***:

1. Year of sampling: 85.0 centimeters,
2. Mean annual: 59.9 centimeters.

† Table of metric conversions--Appendix B.
†† Weems, 1976.
††† For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
* Sum of inflows adjusted to equal sum of outflows plus evaporation; see page 10.
** Includes area of lake.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Lake Fort Phantom Hill was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at three stations on the lake (see map, page vi). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the October visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 15.8 meters at station 1, 10.7 meters at station 2, and 6.1 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table.

[illegible] SUMMARY OF [illegible] ALL [illegible] CHARACTERISTICS FOR [illegible]
[illegible]

PARAMETER	1ST SAMPLING	2ND SAMPLING	3RD SAMPLING
	3 SITES	3 SITES	3 SITES
	RANGE MEAN MEDIAN	RANGE MEAN MEDIAN	RANGE MEAN MEDIAN
TEMP (C)	11.5 - 15.4 13.7 13.4	23.8 - 24.5 24.2 24.1	25.5 - 26.4 26.1 26.3
DISS OXY (MG/L)	6.0 - 6.4 6.2 6.3	7.0 - 7.4 7.2 7.2	5.2 - 7.8 6.5 6.8
CNDCTVY (MICRO)	455. - 666. 535. 538.	454. - 458. 456. 457.	661. - 667. 664. 665.
PH (STAND UNITS)	6.1 - 6.4 6.3 6.3	6.1 - 6.3 6.3 6.3	6.2 - 6.4 6.3 6.3
TOT ALK (MG/L)	167. - 173. 170. 170.	165. - 170. 167. 168.	162. - 167. 164. 164.
TOT P (MG/L)	0.024 - 0.027 0.026 0.026	0.047 - 0.054 0.050 0.051	0.044 - 0.074 0.056 0.056
ORTHO P (MG/L)	0.019 - 0.020 0.020 0.020	0.037 - 0.043 0.040 0.039	0.035 - 0.062 0.050 0.049
NO2+NO3 (MG/L)	0.038 - 0.046 0.042 0.042	0.046 - 0.062 0.054 0.054	0.038 - 0.058 0.049 0.048
AMMONIA (MG/L)	0.038 - 0.060 0.047 0.046	0.035 - 0.060 0.049 0.050	0.033 - 0.078 0.054 0.055
KJEL N (MG/L)	0.460 - 1.200 0.845 0.880	0.260 - 1.100 0.580 0.450	0.330 - 0.580 0.460 0.460
INORG N (MG/L)	0.460 - 0.570 0.496 0.490	0.470 - 0.540 0.509 0.510	0.540 - 0.560 0.550 0.555
TOTAL N (MG/L)	0.460 - 1.240 0.696 0.570	0.270 - 1.100 0.559 0.585	0.330 - 0.530 0.405 0.405
CHLOPHYL A (UG/L)	2.5 - 3.1 3.0 3.1	4.9 - 7.8 5.9 5.8	13.7 - 25.3 20.7 20.4
SECCHI (METERS)	0.6 - 0.8 0.7 0.8	0.2 - 0.5 0.3 0.3	0.6 - 0.8 0.6 0.6

[illegible]

[illegible]

PARAMETER	RANGE	MEAN	MEDIAN
TEMP (C)	23.0 - 24.2	24.1	23.9
DISS OXY (MG/L)	6.4 - 7.6	7.2	7.2
CNDCTVY (MICROMHO)	372. - 434.	396.	402.
PH (STAND UNITS)	7.9 - 8.0	8.0	8.0
TOT ALK (MG/L)	112. - 128.	117.	116.
TOT P (MG/L)	0.091 - 0.094	0.092	0.092
ORTHO P (MG/L)	0.062 - 0.068	0.073	0.073
NO2+NO3 (MG/L)	0.278 - 0.292	0.279	0.280
AMMONIA (MG/L)	0.039 - 0.059	0.041	0.040
KJEL N (MG/L)	0.380 - 0.485	0.400	0.400
ORG N (MG/L)	0.330 - 0.340	0.320	0.320
TOTAL N (MG/L)	0.570 - 0.698	0.679	0.679
CHLOPYL A (UG/L)	1.3 - 1.9	1.7	1.8
SECCHI (METERS)	0.6 - 0.6	0.6	0.6

8. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/06/74	1. Chroomonas sp.	706
	2. Selenastrum sp.	445
	3. Microcystis sp.	131
	4. Cryptomonas sp.	105
	5. Dactylococcopsis sp.	78
	Other genera	183
	Total	1,648
06/15/74	1. Chroomonas sp.	743
	2. Microcystis sp.	496
	3. Cryptomonas sp.	212
	4. Centric diatoms	177
	5. Euglena sp.	177
	Other genera	744
	Total	2,549
08/05/74	1. Coscinodiscus sp.	3,378
	2. Chroomonas sp.	622
	3. Chlamydomonas sp.	445
	4. Zoospores	356
	5. Merismopedia sp.	267
	Other genera	1,022
	Total	6,090
10/30/74	1. Chroomonas sp.	803
	2. Oocystis sp.	223
	3. Chlamydomonas sp.	178
	4. Centric diatoms	178
	5. Microcystis sp.	134
	Other genera	402
	Total	1,918

F. Chlorophyll A -

Sampling Date	Station Number	Chlorophyll A (ug/l)
03/06/74	1	3.1
	2	2.9
	3	3.1
05/15/74	1	5.0
	2	4.9
	3	7.8
08/05/74	1	13.7
	2	15.3
	3	15.0
10/30/74	1	1.3
	2	1.9
	3	1.8

G. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.031	0.207	6.2
0.050 P	0.081	0.207	6.3
0.050 P + 1.0 N	0.081	1.207	25.9
1.0 N	0.031	1.207	15.9

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Fort Phantom Hill was high at the time the sample was collected (10/30/74).

There was a significant increase in yield when only nitrogen was added, but not when phosphorus alone was added. Based on these results, nitrogen limitation is indicated at that time.

The lab data indicate nitrogen limitation at all sampling times; i.e., the mean inorganic nitrogen to orthophosphorus ratios were 8 to 1 or less at all sampling stations and times. However, the mean Secchi disc transparency of 0.6 meters indicates primary productivity may be light-limited at times rather than nutrient-limited.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake. Several factors affect the flow into and out of Lake Fort Phantom Hill. The City of Abilene diverts about 0.66 m^3/sec from the reservoir for municipal use (Anonymous, 1976), and water is pumped from the Clear Fork Brazos River into the lake at an average rate of 0.24 m^3/sec (Weems, 1976). Apparently, the variability of flow is high and is sometimes affected by irregular inflows such as the diversion of an undetermined amount of flood flow by gravity ditch from Deadman Creek to the reservoir (Anonymous, 1976).

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in Elm Creek at station A-2 and the mean annual ZZ flow.

No known wastewater treatment plants impacted Lake Fort Phantom Hill during the sampling year.

A. Waste Sources:

1. Known municipal - None

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Elm Creek	555	13.8
Cedar Creek	456	11.3
Clear Fork Brazos River diversion	970	24.1
b. Minor tributaries & immediate drainage (non-point load) -	1,730	43.0
c. Known municipal STP's - None	-	-
d. Septic tanks* -	125	3.1
e. Known industrial - None	-	-
f. Direct precipitation** -	190	4.7
Total	4,025	100.0

2. Outputs -

Lake outlet - Abilene Aqueduct	1,080	
Elm Creek	470	
Total	1,550	

3. Net annual P accumulation - 2,475 kg.

* Estimate based on 441 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Elm Creek	10,020	11.0
Cedar Creek	6,470	7.1
Clear Fork Brazos River diversion	25,515	27.8
b. Minor tributaries & immediate drainage (non-point load) -	32,645	35.6
c. Known municipal STP's - None	-	-
d. Septic tanks* -	4,700	5.1
e. Known industrial - None	-	-
f. Direct precipitation** -	11,800	12.9
Total	91,650	100.0

2. Outputs -

Lake outlet -	Abilene Aqueduct	17,060
	Elm Creek	7,190
Total		25,050

3. Net annual N accumulation - 66,600 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Elm Creek	<1	16
Cedar Creek	1	16

* Estimate based on 441 lakeshore dwellings; see Working Paper No. 175.
** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Stream:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Buck Creek	0.049	2.202

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.37	0.23	8.4	6.1

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Lake Fort Phantom Hill:

"Dangerous" (eutrophic loading)	0.32
"Permissible" (oligotrophic loading)	0.16

V. LITERATURE REVIEWED

Anonymous, 1976. Water resources data for Texas, water year 1975. Water-Data Rept. TX-75-1, U.S. Geol. Surv., Austin.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Weems, W. J. (Water Supt.), 1976. Personal communication (diversions from lake for municipal use; lake morphometry; pumping records for Clear Fork Brazos River). Abilene.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

[illegible]

[illegible] CODE	LAKE NAME	[illegible] TOTAL *	[illegible] [illegible] *	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible] *
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[illegible]	[illegible] LAKE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	E + [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] Data To Be Used In Rankings

Lake Code	Lake Name	[illegible] Total *	[illegible] Index *	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible] *
[illegible]	[illegible] Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Lake [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] [illegible] [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] (PERCENT OF LAKES WITH HIGHER VALUES) (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] [illegible] P	[illegible] MEAN DEC	[illegible] CHLORIDE	[illegible] [illegible]	[illegible] [illegible] [illegible] P	[illegible] NO
[illegible]	[illegible] LAKE	45 (36)	5 (2)	168 (38)	108 (28)	19 (14)	43 (23)	[illegible]
[illegible]	[illegible] LAKE	76 (32)	74 (29)	62 (31)	47 (18)	17 (8)	92 (34)	[illegible]
[illegible]	[illegible] RESERVOIR	62 (35)	26 (10)	67 (37)	68 (26)	17 (6)	84 (31)	[illegible]
[illegible]	[illegible] LAKE	5 (2)	42 (16)	55 (19)	8 (3)	48 (17)	5 (2)	[illegible]
[illegible]	[illegible] LAKE	68 (25)	78 (28)	29 (11)	87 (33)	58 (22)	84 (31)	[illegible]
[illegible]	LAKE [illegible]	47 (18)	21 (7)	74 (28)	62 (24)	17 (6)	74 (28)	[illegible]
[illegible]	CADDO LAKE	36 (18)	91 (33)	42 (16)	32 (12)	76 (29)	38 (10)	[illegible]
[illegible]	CALAVERAS LAKE	45 (17)	108 (38)	47 (18)	11 (4)	67 (25)	92 (34)	[illegible]
[illegible]	CANYON RESERVOIR	68 (27)	8 (3)	95 (36)	97 (37)	48 (17)	97 (37)	[illegible]
[illegible]	LAKE COLORADO CITY	36 (14)	76 (29)	21 (10)	42 (16)	88 (33)	38 (14)	[illegible]
[illegible]	CORPUS CHRISTI LAKE	0 (3)	47 (18)	18 (7)	13 (5)	61 (23)	0 (3)	[illegible]
[illegible]	[illegible] LAKE	68 (26)	63 (31)	32 (12)	29 (11)	97 (37)	63 (21)	[illegible]
[illegible]	EAGLE [illegible] LAKE	72 (27)	91 (33)	34 (13)	74 (28)	79 (30)	76 (29)	[illegible]
[illegible]	FT [illegible] HILL LAKE	24 (9)	66 (25)	21 (8)	74 (28)	95 (36)	26 (6)	[illegible]
[illegible]	GARZA LITTLE ELM RESERVO	34 (13)	13 (5)	26 (9)	34 (13)	55 (21)	21 (7)	[illegible]
[illegible]	HOUP LAKE	78 (29)	61 (23)	55 (21)	55 (21)	84 (32)	92 (34)	[illegible]
[illegible]	[illegible] LAKE	26 (9)	36 (9)	8 (0)	24 (9)	72 (27)	11 (4)	[illegible]
[illegible]	LAKE OF THE PINES	54 (20)	78 (26)	66 (25)	39 (15)	17 (0)	46 (17)	[illegible]
[illegible]	LAVON RESERVOIR	21 (8)	29 (11)	3 (1)	84 (32)	100 (38)	21 (7)	[illegible]
[illegible]	LEWISVILLE LAKE	3 (1)	3 (1)	79 (15)	26 (10)	17 (0)	3 (1)	[illegible]
[illegible]	LYNDON B JOHNSON LAKE	38 (14)	11 (4)	53 (20)	66 (25)	38 (14)	30 (10)	[illegible]
[illegible]	[illegible] LAKE	66 (27)	0 (0)	99 (36)	27 (10)	17 (0)	100 (38)	[illegible]
[illegible]	LAKE [illegible]	62 (23)	91 (33)	71 (27)	95 (36)	38 (14)	63 (23)	[illegible]
[illegible]	PALESTINE LAKE	54 (20)	32 (12)	63 (24)	53 (20)	48 (17)	51 (19)	[illegible]
[illegible]	[illegible] [illegible] [illegible]	76 (29)	91 (33)	84 (32)	58 (22)	17 (6)	63 (23)	[illegible]
[illegible]	SAN [illegible] RESERVOIR	13 (5)	45 (17)	0 (0)	8 (0)	88 (33)	46 (17)	[illegible]
[illegible]	SAN [illegible] RESERVOIR	59 (23)	39 (15)	68 (26)	76 (29)	17 (6)	63 (23)	[illegible]
[illegible]	E O SPENCE RESERVOIR	58 (19)	63 (33)	45 (17)	58 (19)	17 (6)	76 (28)	[illegible]

[redacted]

LAKE CODE	LAKE NAME	[redacted] TOTAL #	[redacted] INDIV. %	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

LAKES RANKED BY INDEX NO.

RANK	LAKE CODE	LAKE NAME	INDEX NO.
1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]

[illegible] [illegible] [illegible]

[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	259
30	[illegible]	[illegible]	257
31	[illegible]	[illegible]	256
32	[illegible]	[illegible]	255
33	[illegible]	[illegible]	176
34	[illegible]	[illegible]	173
35	[illegible]	[illegible]	169
36	[illegible]	[illegible]	159
37	[illegible]	[illegible]	155
38	[illegible]	[illegible]	139
39	[illegible]	[illegible]	91

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TO	DAY	FEET	DEG F	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/15/1994	16	53	0000	24.1		24	992	8.38	172	8.206	8.459	8.429
	16	53	0005	24.4	4.2		992	8.38	173	8.246	8.468	8.433
7/15/15	09	48	0000	24.5		0	651	8.35	249	8.242	8.530	8.444
	09	58	0005	24.6	7.6		658	8.38	194	8.269	8.356	8.446
7/16/95	09	05	0000	25.6	6.6	24	991	8.44	192	8.256	8.455	8.398
	09	05	0005	25.6	6.6		991	8.46	193	8.246	8.468	8.425
7/18/38	22	15	0000	24.4	7.8	24	487	8.28	225	8.248	8.468	8.276
	22	15	0005	24.4	8.4		410	7.45	128	8.258	8.468	8.276
	22	15	0015	24.4	7.2		414	7.45	225	8.246	8.376	8.276
	22	15	0020	24.6	7.*		409	7.45	229	8.258	8.384	8.276

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TO	DAY	FEET	[illegible]	[illegible]	[illegible]
7/15/94	16	53	0000	8.246	3.1
	16	53	0005	8.245	
7/15/15	09	58	0000	8.258	7.8
	09	58	0005	8.529	
7/16/95	09	05	0000	8.274	15.4
	09	05	0004	8.258	
7/18/38	22	15	0000	8.246	1.4
	22	15	0005	8.245	
	22	15	0015	8.247	
	22	15	0020	8.246	

APPENDIX E

TRIBUTARY DATA

[illegible]

[illegible]

[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7/4/1997	11	15	0.816	0.498	0.945	0.810	0.948
7/4/1925	12	35	0.225	0.588	0.438	0.864	0.386
7/4/1982	13	39	0.296	0.586	0.827	0.957	0.183
7/4/1987	11	88	0.328	0.588	0.832	0.878	0.886
7/5/1994	14	45	0.369	0.788	0.940	0.955	0.878
7/5/1981	10	55	0.396	0.888	0.980	0.944	0.828
7/6/1981	11	25	0.228	0.258	0.866	0.835	0.946
7/6/1985	15	85	0.810	0.456	0.838	0.818	0.838
7/6/1994	14	55	0.875	[illegible]	0.266	0.828	0.186
7/7/1983	10	15	0.818	0.958	0.885	0.815	[illegible]
7/8/1917	11	48	0.818	0.358	0.815	0.865	0.918
7/8/1987	11	15	0.346	0.788	0.961	0.815	0.828
7/8/1985	11	46	0.965	0.888	0.828	0.859	0.946
7/9/1982	87	46	0.815	0.458	0.828	0.828	0.128

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
74/10/07	09	46		0.438	0.455	0.025	0.422	0.385
74/10/08	10	28		0.578	0.536	0.013	0.010	0.496
74/11/02	04	45		0.352	0.488	0.295	0.045	0.238
74/12/07	10	08		0.498	0.100	0.024	0.015	0.028
75/01/04	13	55		0.629	0.786	0.016	0.019	0.635
75/02/01	09	05		0.825	0.385	0.044	0.158	0.216
75/03/01	13	39		0.805	0.468	0.035	0.005	0.025
75/04/05	13	58		0.776	0.458	0.058	0.005	0.046
75/04/19	12	59		0.438	0.100	0.048	0.005	0.070
75/05/13	17	07		0.718	0.558	0.025	0.018	
75/05/17	10	42		0.678	0.588	0.015	0.015	0.096
75/06/07	10	08		0.428	0.558	0.038	0.035	
75/07/05	10	05		0.498	0.488	0.028	0.0054	0.070
75/08/02	06	10		0.928	0.458	0.015	0.025	0.286

[illegible]
[illegible]

[illegible]

[illegible]
32 39 48.3 099 41 25.0 W
[illegible] CREEK
48 1.5 [illegible]
TAL: FORT [illegible]
[illegible] 48 2433 9866 2 41 0 SF MAY 351
[illegible]
[illegible] FEET DEPTH 0.465 M

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	N	[illegible]	[illegible]	
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P
[illegible]	11	00	1.440	1.380	0.838	0.420	0.040
[illegible]	11	50	0.480	1.500	1.065	0.430	0.380
[illegible]	10	35	0.620	1.480	1.040	0.485	0.420
[illegible]	14	15	1.060	0.800	1.040	0.485	0.420
[illegible]	09	55	1.130	1.480	0.980	0.460	0.320
[illegible]	13	45	1.575	1.500	0.965	0.4854	0.410
[illegible]	14	15	1.125	1.650	1.070	0.415	
[illegible]	13	35	0.455	1.460	0.960	0.410	0.430

[illegible] VALUE [illegible] TO BE
LESS THAN [illegible]

[illegible]

[illegible]
[illegible]
[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] HISTORICAL DATA INVENTORY

[illegible]
32 3: 25.0 [illegible] 2 10.0 =
[illegible] [illegible]
[illegible] 5.0 [illegible]
[illegible] [illegible]
[illegible] [illegible] [illegible] 0.5 [illegible]
[illegible]
[illegible] [illegible] 0.0 [illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	TO		[illegible]	N	[illegible]	[illegible]	
YR	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P
74/07/07	11	75	0.490	1.200	0.035	0.025	0.105
74/10/05	12	50	5.240	0.485	0.015	0.020	0.110
74/11/02	10	85	1.520	1.300	0.040	0.005	0.290
74/12/07	11	30	4.480	0.480	0.032	0.005	0.010
75/01/04	14	90	4.540	0.700	0.032	0.030	0.092
75/02/01	11	35	4.040	1.200	0.030	0.040	0.190
75/03/01	14	40	4.300	1.300	0.045	0.005	0.090
75/04/25	15	35	1.050	0.480	0.025	0.005	0.040
75/04/19	15	20	2.480	1.500	0.070	0.007	0.070
75/05/01	10	40	1.720	0.350	0.055		0.010
75/05/17	12	15	2.630	0.700	0.015	0.000	0.120
75/06/01	11	40	1.250	1.700	0.055	0.100	0.040
75/07/05	12	20	1.100	1.230	0.025	0.040	0.140
75/08/02	10	20	1.060	1.450	0.020	0.060	0.150

A VALUE PREFIXED TO BE
LESS THAN INDICATED